This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

STANFORD
LIBRARIES

Dr. J. C. Branner
with Compliments of the Author
P14-391

The Stratigraphy of the Western American Trias

By J. P. SMITH,
Stanford University, California U.S.A.

Sonder-Abdruck
aus der Festschrift zum
siebzigsten Geburtstage
von Adolf v. Koenen
gewidm. v. seinen Schülern

STANFORD LIBRARY

SCHWEIZERBART'SCHE VERLAGSBUCHHANDLUNG, STUTTGART 1907.

STANFORD LIBRARY

Branner Earth Sciences Library

Stanford Library

The Stratigraphy of the Western American Trias.

By J. P. Smith, Stanford University, California U. S. A.

Contents.

Interregional Correlation.
- Palaeontologic zones.

Ancient faunal Relations.
- Palaezoic Times.

Interregional Correlation of the Trias.
- Geography of the American Trias.
- Faunal relations of the western American Trias.

The Lower Trias.
- The Meekoceras beds of Idaho.
- The Meekoceras beds of California.
- The Tirolites beds.
- The Columbites beds.

The Middle Trias.
- The Middle Trias of California.
- The Middle Trias of Nevada.

The Upper Trias.
- Plumas County, California.
- Shasta County, California.
- The Upper Trias, Noric Horizon.

Geographic relations of the American Trias.

Summary of later stratigraphy of Western America.
- Lias.
- Middle Jura.
- Upper Jura.

212480

56 .1
S61
no.2

Lower Cretaceous.
Upper Cretaceous.
Eocene.
Miocene.
Pliocene.

Pleistocene and recent faunal relations.
San Pedro epoch.
Relations of the living faunas of the west coast to those of Japan.
Tertiary and living species.

Summary.
Present physical geography.
On homotaxis.
On the permanence of the shore line.

Interregional correlation.

Geologic correlation has been carried on ever since the pupils of WERNER endeavored to recognize his stratigraphic divisions in remote parts of the earth; and since WILLIAM SMITH discovered that fossils are characteristic of certain formations, palaeontologic correlation has been attempted. Still it must not be forgotten that the greater part of the correlation that has been done up to this time is based on physical, lithologic and stratigraphic rather than on faunal data. Fossils have been regarded as incidental, useful in recognizing strata, but not as a basis subdivisions account of changes in fauna or flora.

Where a rock-bed of distinctive charakter is persistent over a wide extent of country, a lithologic correlation would reach as good, and often even better, results than could be obtained from paleontologic data. But outcrops of strata are deceptive, and often apparently continuous beds of the same character turn out to contain a number of different formations. In the western states such lithologic and stratigraphic correlations have been, more often than not, erroneous, while in the Mississippi valley region they

have usually been at least approximately correct, because the great geologic events that were the causes of the stratigraphic changes were uniform over wide areas. Even today the catastrophe doctrine of Cuvier makes itself felt, and we find paleontologists and stratigraphers using unconformities as a basis for the separation of Cretaceous from Jurassic, where the fossils do not tell a definite story, as if the uplift and erosion would necessarily come at the same time in Europe and America.

Paleontologic correlation itself is not infallible; it must be used intelligently, its sources of error known and guarded against, or else it is little more reliable than the lithologic method; these errors lie chiefly in defective knowledge of the vertical and horizontal range of species or genera chosen as criteria, and in erroneous identification of these forms. Careful collecting, accurate field and laboratory discrimination, and wide knowledge of the literature are the best safeguards.

Two sorts of paleontologic correlation may be recognized, the direct, and the indirect method. In a limited province, such as existed in England and France during Cretaceous time, faunas were distributed uniformly over the area and had the same range in the two countries. Thus correlation of English and French Cretaceous strata is simple and direct, for they represent sediments that were once continuous, that were laid down in the same basins or along the same margins, under the same climatic conditions, and contained the remains of a similar fauna.

On a larger scale the problem of correlating the western European Cretaceous beds with those of the Atlantic slope Cretaceous of North America is the same. These strata were all deposited in the same faunal region, and although there are provincial differences, the American and the western European faunas are remarkably similar, with even many species in common to the two provinces, and most of the genera. During Cretaceous time there must have been easy intercommunication between Europe and

America by a submerged continental shelf, keeping well within the temperate conditions. This state of things persisted through the Eocene, for the same similarity of faunas has been noted on the two continents in strata of that period.

On a still larger scale the same sort of correlation has been carried out between the western American and the Alpine Upper Trias, where many of the species and nearly all the genera are common to the two localities, although they are not in the same province, nor even in the same faunal region, and separated by six thousand miles in a direct line. Yet there must have been easy intercommunication by continental margins from the American region to the Mediterranean region, along the borders of the ancient Mesozoic »Tethys« or central Mediterranean sea, that stretched eastward from the Alpine province through Asia Minor, India, and at least to the borders of China and Japan.

Direct correlation is possible even where there is no community of species, if a number of characteristic short-lived genera be common to the two regions. Thus the student of stratigraphic paleontology has no difficulty in correlating the *Meekoceras* beds of the Lower Trias, whether they occur in the Himalayas, Siberia, California, or Idaho; the fauna is essentially similar in all these regions, although species common to them are not yet certainly identified. These faunas must have had a common origin either in one of these regions or in some unknown outside region, and reached the American and Asiatic provinces by migration. The place of origin may have been distant enough for the migrant faunas to have become specifically differentiated by the time they had reached their distant goals. In fact this is probably by far the more common case. Absolute specific identity between regions as distant as Asia and America must be rare; in reality there are usually in common to such regions only what are called »representative species«. This is especially true in a time of quiet development, where the

fauna is largely endemic, and where there was no chance for outside elements to get into the region.

Indirect correlation also may be of two kinds; the first of these is where no fossils of extra-regional distribution are known in a formation, but where the formations above and below can be recognized. An example of this is the classification of the Algonkian system or its equivalents; the clastic pre-Cambrian, and post-Archean sediments all over the world are placed in this division, although no fauna that is characteristic is known in them as yet. Such correlation can only be tentative or preliminary, as is the present classification of the Newark formation of the Atlantic coast.

The second sort of indirect correlation is where no fossils are common to two separated regions, but elements of both are found together in a third region. A good example of this is the correlation of the Cretaceous strata of the west coast of North America with those of the interior and the Atantic region. During the greater part of Cretaceous time the two regions were separated by a land mass so that their faunas were totally distinct, not only the species but even the genera being different. And these difficulties are seen in the attempts of the earlier stratigraphers to assign the various formations to their proper places. But when the Indian Cretaceous fauna was described, it was seen at once that there were striking analogies between that and genera and species of California. And since the Indian formation was accurately correlated with the Cretaceous of Europe, it became comparatively easty to assign the Californian strata to their proper place by this indirect comparison with the European standard. The Cretaceous of the Atlantic region had long before this been correlated with European, and thus the formations of the Atlantic region and of the Pacific coast were finally placed in harmony trough the medium of comparison with a region thousands of miles from either.

Paleontologic zones. Ever since WILLIAM SMITH demonstrated that

the various beds of the English Jurassic may be recognized by their fossils, the stratigraphy and paleontology of this formation have been a favorite field for investigation. Jurassic strata with abundant marine fossils are widely distributed in England, France, Germany, and Switzerland, in easy reach of universities and museums, so that the student of these faunas has an unusual wealth of material at hand. And in this western European province comparatively uniform conditions prevailed during the greater part of this time, allowing the faunas to become widely distributed. It is doubtful if any other succession of fossil faunas in the world is so well known as that of the Jurassic of this province, or if anywhere else such minute stratigraphic and faunal division has been successfully carried out; for there is not a single bed in all the great thickness of Jurassic sediments that does not contain somewhere in this province a rich marine fauna.

QUENSTEDT devoted his life to a minute subdivision of the Jurassic of Württemberg, establishing a classification that still holds sway in Germany; but this classification was based on local faunas, whose appearance and disappearance were caused by local changes in sedimentation, and it could hardly be used away from the place where it originated. In this scheme the greater unconformities, overlaps, and faunal changes received no more attention than the smaller geologic events. It was, however, a useful local classification, of great value as a starting point in comparative study.

It was reserved for ALBERT OPPEL[1], a pupil of QUENSTEDT, to establish a chronological classification, based entirely on paleontology, and independent of lithologic development. For the entire Jurassic formation OPPEL recognized thirty-three zones, or subdivisions characterized by certain species that occurred only in these horizons. The species chosen were of the greatest horizontal and the least vertical distribution, and were usually

[1] Die Jura-Formation, 1856.

ammonites. These zones were thought by OPPEL to be universal, for he was able to recognize them in Germany, Switzerland, France, and England, and by means of them was able to bring into harmony the local subdivisions already established in these various countries.

This was an important step in the right direction, but experimence has sown, since OPPEL's time, that these zones were not universal, and could seldom be recognized outside of the province where they were established — not even there always, when there was much difference of facies. So this scheme failed of its immediate purpose, although the final results of it have been more important than OPPEL probably ever anticipated.

A further application and enlargement of OPPEL's plan has been attempted by BUCKMAN,[1] who has divided the Jurassic formation into *hemerae*, based on the occurrence of certain characteristic species of ammonites. An *hemera* represents a time considerably shorter than a zone, for the Lias, or Lower Jura, alone is divided into twenty-six *hemerae*. These are undoubtedly of much use to the stratigraphic paleontologist in England, probably in France, and possibly in Germany; but these *hemerae* can not possibly be identified away from the limited province where they were established, for in the Alpine or the Austrian Jura one is often lucky to be able to tell whether certain beds belong to Lower, Middle, or Upper Jura. Such finely drawn subdivision is of use only in local stratigraphy.

BUCKMAN further classed a number of *hemerae* together in *ages*, based on the development of a group or series of species; in the Lias alone there are four of these *ages*, which correspond more nearly to the zones of OPPEL, but even these could hardly be recognized in southern Europe, and much less in Asia or America.

OPPEL thought that his zones were universal, or interregional, but

[1] Quart. Jour. Geol. Soc. London. Vol. LIV, 1898. On the Grouping of some Divisions of so-called Jurassic Time.

only occasionally can one of them be identified outside of the province where it was named. This is due to the distribution of certain characteristic fossils outside of their usual range, on account of conditions temporarily facilitating interregional migrations, which can occur only at times of readjustment of faunal provinces. There can be none in the intermediate periods of stability and quiescence when the fauna is endemic.

I propose to retain the term »zone«, in the sense intended by OPPEL, as a chronologic term for a limited horizon, or time division, characterized by an interregional fauna. Use of the term in this significance would recognize not only byologic development, but also geologic events, for an interregional fauna can appear only in times of readjustment of biologic regions, of transgressions of the sea on the land, or of opening up connections between regions that before were separated. These are nature's periodic trial balances, during which the geologic columns in various regions, for a while divergent in biologic development and thus in stratigraphic classification, are brought into harmony.

A zone, in this sense, means a comparatively short time in which a certain characteristic, limited group of animals or plants lived—too short for any great faunal change, but long enough for this group to diffuse itself over a great area. To illustrate this let us take a well known example. It must have taken a long time for *Productus semireticulatus* to be dispersed through the seas of Australia, Eurasia, and America, for it is found in all those regions. But no stratigrapher would choose this species as a zone fossil, since it ranges from the Mountain Limestone into the Permian; often characteristic of a certain province during a given time, but of no one horizon everywhere. And during this long time the greater part of the accompanying faunas underwent enormous changes, until most of the genera, even, were new. During all these migrations *Productus semireticulatus* itself underwent modifications until it might be divided into a number of geo-

graphic species or varieties, and each of these into mutations or varieties in an upward-ranging genetic series. But accompanying *Productus semireticulatus* there are many species and genera that were short-lived and widely distributed, in some one region appearing as a link in a genetic series, but in some other region appearing sporadically or unheralded by local ancestors, and brought in by immigration from the outside world. The appearance of such genera or species is an interregional event, and marks an episode in the dynamic history of the earth. Zones are thus not a figment of the stratigrapher's imagination, but are based on geologic events of far-reaching importance, in comparison whith which the local shiftings of lithologic facies are insignificant.

Ancient Faunal Relations.

The fossil marine faunas of the western coast of the United States, of British Columbia, Alaska, Japan, and India are fairly well known, especially in the Mesozoic era. These faunas are now similar, now different in the various provinces, or in parts of them, presenting an apparently inextricable confusion not capable of any rational explanation. But this confusion is only apparent, for when the faunas are studied in succession, a regular scheme can be traced in the relationships and diversities of this ancient region. And the changes that are noted point to changes in physical geography that would be insignificant in themselves, compared with continental uplifts and subsidences, though by no means insignificant in their effects. Also there is abundant independent physical evidence that these changes really took place, so they are in no sense merely hypothetical.

There is at present a remarkable similarity in the living marine molluscs of the western coast of North America and of the eastern coast of Asia in approximately the same latitudes, and this similarity can be traced back

with certainty until the Lower Trias, and probably even below that. But the resemblance is not continuous, there being periods in which the faunas were unlike, and these periods of interruption recur several times, although not regularly. It is clear that no migration is taking place between the opposite sides of the Pacific now, and equally clear that such migration did go on in comparatively recent geologic time, when a large part of the present species of marine invertebrates already existed. It is necessary to state the facts in succession in order to show how the intermigration must have taken place, and the cause of the periodic interruptions, reasoning back always from modern conditions to those of the past.

Paleozoic time. We know little with certainty of the faunal geography of the Paleozoic of the western coast of America, except that during the Carboniferous the connection seems rather to have been with northern Asia than with the interior of North America. This is especially marked in the Lower Carboniferous, but becomes less so during the Coal Measures. The kinship of American and Asiatic forms can not be charged to universality of faunas or physical conditions, for we know that there was nearly as much provincial differentiation in the marine Carboniferous as there is now.

Interregional Correlation of the Trias.

(Compare the table p. 392 and 393.)

Geography of the American Trias. During Triassic time the sea, which had covered the greater part of the Mississippi Valley and the Great Basin in the Upper Carboniferous, had retreated westward until it was reduced to a mere gulf in the Great Basin region. Sediments with marine fossils of the Lower Trias are known on the North American continent only in eastern California and southeastern Idaho; marine fossils of the Middle

Trias are known only in California, central Nevada, and, somewhat doubtfully, in eastern Oregon; while Upper Triassic marine fossils are known only in northern California, central Nevada, western British Columbia, on Queen Charlotte and Vancouver islands, and on the shores of Alaska.

During the Lower Trias the gulf extended as far eastward as the Aspen Mountains of Idaho; during the Middle Trias it retreated westward until its eastern border was in central Nevada; and at the end of the Trias the land had encroached still further until the gulf was little more than a bay in northern California and central Nevada, with similar bays in western British Columbia.

Around this western gulf extended the inlets and continental basins in which were deposited the Triassic Red Beds. These extend in a fringe around the marine sediments, from the Grand Canyon region on the south, along the Rocky Mountains, up into British Columbia.

As the sea retreated westward the brackish water and continental basins followed it; thus the Triassic Red Beds do not all belong to one horizon, but take a successively higher place in the geological column towards the west. In Oklahoma the Red Beds contain Permian fossils of brackish water origin; in northwestern Texas they contain fresh water Triassic fossils. In southeastern Idaho the marine sediments of Lower Triassic age are overlain by barren red sandstones representing the Middle Trias. And in northern California, after the Hosselkus limestone and Brock shales epoch, a series of red sandstones were depointed containing only fossil plants of Rhaetic age.[1] Further than this the incroachment did not go, for in California and Nevada the next epoch, the Lias, is characterized by a marine fauna, showing a renewed subsidence and transgression of the interior sea over a large part of the area covered during the Lower Trias.

[1] W. M. FONTAINE, Twentieth Annual Report., Part. II, U. S. Geol. Survey (1900), p. 333.

The continental deposits of the Trias in western America bear all the marks of products of an arid region, very like the conditions at present existing in the region of the Caspian Sea of to-day. But that the marine Triassic sediments were laid down in an arm of the greater ocean, and not in a closed basin analogous to the Caspian Sea is shown by the fact that their successive faunas show a close relation to forms that existed contemporaneously in other regions bordering on the Pacific Ocean, and in the ancient Mediterranean Sea or Tethys, which in the Mesozoic time covered a large part of southern Asia.

At the close of the Trias we see the culmination of that progressive elevation of the land that began in the Mississippi Valley at the beginning of the Coal Measures, and extended gradually across the American continent until all that was left of the great interior sea was merely a gulf a few hundred miles across. This odds another chapter to the remarkably uniform history of North America which has been recorded in the rhythmical advance and retreat of the sea across its surface from the Cambrian to the Tertiary. Each period of subsidence, local or widespread, has been followed by a period of elevation in which the continent resumed approximately its former shape and extent. Whatever may have been the development of other continents, North America has been a unit since its history began to be recorded in the Pre-Cambrian sediments laid down in the first sea that covered its surface.

The Lower Trias.

I have already shown in several papers[1] that the Lower Triassic *Meekoceras* fauna of California and the Great Basin shows an intimate relation-

[1] Jour. Geol., VI, 776–786, 1898; Jour. Geol., IX, 512–521, 1901; Proc. California Acad. Sci., III. Ser., Geol. Vol. I, 325–430, 1904; Prof. Papers No. XL, U. S. Geol. Survey, 1–394, 1905.

Faunal relations of the Western American Trias.

Upper Trias	*Pseudomonotis subcircularis* slates, with a fauna of Boreal type, with some Mediterranean forms immingled.
	Tropites subbullatus limestones. with a Mediterranean fauna, and some Indian types immingled.
Middle Trias	*Daonella dubia* limestones, with a Mediterranean fauna, similar to the fauna of the zone of *Ceratites trinodosus*, and with some Indian types.
	Parapopanoceras beds, with a commingling of Boreal and Indian types.
Lower Trias	*Columbites* beds, with a Boreal fauna, and some Indian types, survivors which already had existed in the zone of *Meekoceras gracilitatis*.
	Tirolites beds, with a purely Mediterranean fauna.
	Meekoceras beds, with a purely Asiatic fauna, never been found anywhere else except in India and eastern Siberia.

ship to that of Asia, and none with that of the Mediterranean region. Many genera are represented by closely allied species on both sides of the Pacific Ocean that are wholly unknown in Europe at that time; such are *Flemingites*, *Ophiceras*, *Proptychites*, *Lecanites*, *Aspidites*, *Clypites*, *Pseudosageceras*, *Ussuria*, and many others. Some of the species of these may even be identical, but even without this the association of the genera is such that a paleontologist from Asia would feel himself to be perfectly at home while collecting in eastern California or in Idaho. In some respects the relationship of the fauna of the western coast seems to be closer with that of eastern Asia than with that of India; for instance, *Ussuria*, which is not uncommon in the Meekoceras beds of the Inyo Range in California, and the Aspen Mountains of Idaho, has never been found anywhere else except at Ussuri Bay in eastern Siberia, from which place it was first described. Also *Pseudosageceras intermontanum* is more closely related to the species from Ussuri-Bay than it is to the Indian species of that genus.

These genera are probably not of American origin, and most of them are of unknown antecedents. But, fortunately, the geologic history of some of these forms is known. *Ophiceras*, *Xenaspis*, *Xenodiscus*, and *Hungarites*, which occur in the Trias of Asia and America, chiefly in the lower beds, have also been found in the Permian of southern Asia. To this region, then, we must look for the source most of the Lower Triassic ammonites which appear as immigrants in the American waters, marking the first distinct Asiatic invasion.

After the deposition of the *Meekoceras* beds in Idaho and California an invasion of Mediterranean forms took place, as shown by the occurrence in Idaho of *Tirolites* of the group of *T. cassianus* and *Dalmatites* aff. *morlaccus* in the *Tirolites* beds about 70 metres above the *Meekoceras* beds.

It is noteworthy that, at this time, the Indian region still appears to have been cut off from the Mediterranean. After the *Tirolites* epoch the

Columbites fauna of Idaho had its closest relationship with the Olenek fauna of northern Siberia, and none with either the Mediterranean or the Indian region. The geographic region described by E. von Mojsisovics[1] for the Trias will hold good only for the Lower Trias, and not even for the whole of that epoch.

The Meekoceras beds of Idaho. — The first Lower Trias known in America was found by Dr. A. C. Peale in southeastern Idaho, in a series of fossiliferous limestones lying below the Red Beds and above the Carboniferous limestones. The fossils found here were described by Dr. C. A. White,[2] who assigned them to the Lower Trias. Cephalopods were found at but two places: locality No. 1, in southeastern Idaho, about five miles southeast of John Gray's Lake, Bannock County; locality No. 2, on the divide between Slug Creek and Dry Valley; about fourteen miles east of Soda Springs, and five miles south of Blackfoot River, Bannock County. In the *Meekoceras* beds of these localities were found *Meekoceras gracilitatis, M. mushbachanum, M. aplanatum, Arcestes? cirratus,* described by Dr. White in the work cited above.

Professor Alpheus Hyatt discovered a third locality for this fauna, at the upper end of Wood Canyon, nine miles east of Soda Springs, Bannock County, Idaho; and since that time I have added two more to the list; one on the farm of Otto Rohner, at the mouth of Paris Canyon, one mile west of Paris, Bear Lake County, Idaho; the other, one mile eastsoutheastern of Hot Spring hotel, at the northend of Bear Lake, Idaho. I have spent part of the field seasons of 1900, 1903, 1904, 1905 and 1906 in collecting in the *Meekoceras* beds of southeastern Idaho, and the work at all five of these localities has yielded the following forms (p. 394):

---

[1] Arktische Trias-Faunen (1886) pp. 147—155; and Beitr. Kennt. Obertriadischen Cephalopoden-Faunen des Himalaya (1896), pp. 114—128.

[2] U. S. Geol. and Geogr. Survey of the Territories, 12. Rept. (1880), pp. 105—118.

Interregional

	Series	Stage	Sub-stage	Interregional zone	Mediterranean region			Arctic
	Province				German	Alpine		
Upper Trias	Bajuvaric	Rhaetic			Rhaet			
		Noric		*Pseudomonotis ochotica*	Keuper	Noric limestone of Hallstatt	*Pseudomonotis ochotica* in the Crimea	*Pseudomonotis ochotica* slates of Japan and
	Tyrolic	Karnic	Turalic	*Tropites subbullatus*		Sandling beds with *Tropites subbullatus*		
			Julic			Raibl beds with *Trachyceras aonides*		
			Cordevolic			Cassian beds with *Trachyceras Aon*		slates
		Ladinic	Longobardian	*Daonella Lommeli*		Wengen beds with *Trachyceras Archelaus*		
Middle Trias	Upper Muschelkalk		Fassanic		Upper Muschelkalk	Buchenstein beds with *Trachyceras Reitzii*		Ceratite
	Middle Muschelkalk	Anisic	Bosnian	*Ceratites trinodosus*	Middle Muschelkalk	Reifling limestone	Limestones of Han Bulog, Bakony and the Schrey Alps with *Ceratites trinodosus*	Beds of Usuri Bai in eastern Siberia, with *Monophyllites sichotaicus*
	Lower Muschelkalk	Dinaric	Balatonic		Lower Muschelkalk with *Hungarites Strombecki*	*Ceratites binodosus* beds in the South Alps		
		Hydaspic				Beds at Gulf of Ismid in Asia Minor		
Lower Trias	Scythic	Jacutic		*Tirolites cassianus* in Mediterranean region and Idaho	Buntsandstein	Werfen beds	Campil beds with *Tirolites cassianus*	Olenek be
	Brahmanic	Gangetic		*Meekoceras* fauna in Siberia, India, California and Idaho			Seis beds with *Pseudomonotis Clarai*	beds of northe
		Gandarian						

Oriental region		American region				
Himalaya	Salt Range	California	Nevada	Idaho	Brit. Columb.	
estones with *Halorites* d *Hauerites*		*Pseudomonotis subcircularis* slates with *Rhabdoceras* and *Halorites*	*Pseudomonotis* slates with *Rhabdoceras* and *Placites*		*Pseudomonotis* slates	
Tropite limestone of Kalipani		Hosselkus limestone: *Spiriferina* beds; *Juvavites* beds; Beds with *Tropites subbullatus*; *Halobia superba* beds	Star Peak limestones without characteristic fossils		*Dawsonites* beds	
Beds with *Trachyceras tibeticum*		Hosselkus limestone: Slates with *Halobia* conf. *rugosa*				
Beds with *Trachyceras* conf. *Archelaus* and *Daonella Lommeli*		Pit Formation: Slates and tuffs without determinable fossils			*Daonella* beds	
Beds with *Trachyceras* conf. *ladinum* and *Daonella Lommeli*			*Daonella* limestones in western Humboldt Range: *Gymnites* beds			
ıer Muschelkalk with *ychites rugifer* and *ıtites trinodosus*		Pit Formation: Clay- and silicious slates with *Anolcites* conf. *Whitneyi* and *Ceratites* conf. *humboldtensis*	*Daonella dubia* beds with *Ceratites trinodosus*			
ver Muschelkalk with *ıirites prahlada*		Ceratite limestones of Inyo Range: Black limestones with *Parapopanoceras, Xenodiscus, Acrochordiceras,* and *Hungarites*				
ephanites beds	Ceratite beds: Upper Ceratite limestone	Calcareous slates without fossils		Aspen beds: *Columbites* beds		
denstroemia and *lemingites* beds	Ceratite sandstone			*Tirolites* beds		
leekoceras beds	Ceratite marl	Ceratite limestones of Inyo Range: *Meekoceras* beds of Inyo County, California with *Meekoceras gracilitatis, Ussuria, Pseudosageceras, Inyoites, Owenites, Nannites*		*Meekoras* beds		
Otoceras beds	Lower Ceratite limestone					

Fauna of the Meekoceras beds of southeastern Idaho.

Sibirites conf. *Noetlingi* Hyatt and Smith.
» » *tenuistriatus* Waagen.
Goniodiscus conf. *typus* Waagen.
Danubites aff. *himalayanus* Griesbach.
» *whiteanus* Waagen.
Meekoceras boreale Diener.
» *gracilitatis* White.
» *mushbachanum* White.
» *pilatum* Hyatt and Smith.
» conf. *Hodgsoni* Diener.
» » *euomphalus* Mojsisovics.
» » *Schmidti* Mojsisovics.
» aff. *falcatum* Waagen.
» » *radiosum* Waagen.
» » *boreale* Diener.
» » *fulguratum* Waagen.
Aspidites aff. *davidsonianus* Koninck.
Paralecanites Arnoldi Hyatt and Smith.
Nannites Dieneri Hyatt and Smith.
» conf. *hindostanus* Diener.
Paranannites aspenensis Hyatt and Smith.
Xenaspis sp. nov.
Flemingites aplanatus White.
» *cirratus* White.
» *Russelli* Hyatt and Smith.
» conf. *Rohilla* Diener.
Ophiceras conf. *sakuntala* Diener.
» aff. *gibbosum* Diener.
Inyoites conf. *Oweni* Hyatt and Smith.
Pseudosageceras intermontanum Hyatt and Smith.
Cordillerites angulatus Hyatt and Smith.
Clypites? tenuis Hyatt and Smith.
Lanceolites compactus Hyatt and Smith.

Aspenites acutus HYATT and SMITH.
Hedenstroemia Kossmati HYATT and SMITH.
Ussuria Waageni HYATT and SMITH.
Pseudomonotis idahoensis MEEK.
Undeterminable rests of pelecypods, brachiopods, and fish bones.

These species were found all in the same bed, not thicker than 8 metres. It is not possible to separate this bed into zones, because the species appear everywhere in the rock, with *Meekoceras gracilitatis*, *Flemingites*, *Hedenstroemia*, *Ophiceras*, *Pseudosageceras*, *Cordillerites*, *Ussuria*, *Nanniles* and *Aspidites*, all in the same bed.

During the *Meekoceras* epoch the connection of the American Lower Trias was with India, through southern Siberia and northwestern Thibet (Semenon Mts.), but not through the Boreal regions. Schellwien[1] has described Lower Triassic fossils from northeastern Thibet like those from India and Siberia, and this gives the connection between the two letter regions. The migration was probably around the old Alaskan shore-line to Asia as far as Ussuri Bay, and then through the inland sea through China to India.

The exact stratigraphic position of the *Meekoceras* beds (*Hedenstroemia* beds) of India, has been long a subject of controversy, DIENER regarding them as equivalents of the Werfen beds, and NOETLING placing them lower in the section. The only convincing proof of their age thus far brought out is L. WAAGEN's determination of some Werfen pelecypods in the Salt Range beds. But now since I have discovered a good fauna of the Mediterranean zone of *Tirolites cassianus* in the *Tirolites* beds, about 200 feet above the *Meekoceras* beds in southeastern Idaho, there can be no further doubt about the age of the American *Meekoceras* beds, at any rate. They belong below the Campil beds, and still have a typical Lower Triassic fauna,

[1] Trias, Perm und Carbon in China (1902).

hence they must be regarded as the equivalents of the Seis beds. I am inclined to think that the *Hedenstroemia* beds of India are placed too high in the column.

The *Meekoceras* fauna is probably of Asiatic origin, for there is nothing known in the American Permian that could have given rise to the forms in the *Meekoceras* zone. In India, however, in the Permian and transitional beds there are many forms of the same groupe, and presumptivy ancestral types.

The Meekoceras beds of California. In 1896 Dr. C. D. Walcott discovered some ammonite-bearing limestones in Inyo County, California, on the east side of Owen's Valley, ten miles northeast of Lone Pine, three miles southeast of the Reward mill, and above 500 metres up above the mill, on the »Union Wash« trait from Independence over the Inyo Range to Salinas Valley. These fossils were submitted to me for identification, and were referred to the *Meekoceras* fauna of the Lower Trias, and a preliminary paper[1] about them was published. Later collections made by Mr. H. W. Turner of the U. S. Geological Survey, and by myself on two visits to that region, have added greatly to the list of genera and species, bringing out very strongly the kinship of this fauna with that of the upper Brahmanic faunas of the Asiatic regions.

At the base of the section seen on the »Union Wash« are massive siliceous and calcareous beds that probably belong to the Carboniferous: then several hundred metres of calcareous shales with obscure fossils; then about five metres of hard gray limestone, from which all the fossils listed from this horizon were collected. Above the gray *Meekoceras* limestone lie about 260 metres of darx shales with a few impressions of ammonites; then about 2 metres of impure earthy black limestone with numerous ammonites,

[1] J. P. Smith, Geographic relations of the Trias of California, Jour. Geol. Vol. VI, No. 8, 1893.

Ptychites, *Acrochordiceras*, *Hungarites* etc. This horizon I regard as belonging to the base of the Middle Trias, and it will be more fully treated under that head.

The fauna collected in the gray *Meekoceras* limestone contains the following species:

Fauna of the Meekoceras beds in California.

Sibirites aff. *hircinus* WAAGEN.
» *Noetlingi* HYATT and SMITH.
» aff. *tenuistriatus* WAAGEN.
Goniodiscus aff. *typus* WAAGEN.
Danubites Strongi HYATT and SMITH.
Meekoceras conf. *boreale* DIENER.
» aff. *falcatum* WAAGEN.
» *gracilitatis* WHITE.
» *mushbachanum* WHITE.
» aff. *radiatum* WAAGEN.
Flemingites aplanatus WHITE.
Paralecanites Arnoldi HYATT and SMITH.
Lecanites Knechti HYATT and SMITH.
Prionolobus Jacksoni HYATT and SMITH.
Aspidites Hooveri HYATT and SMITH.
» conf. *eurasiaticus* FRECH.
Nannites Dieneri HYATT and SMITH.
Proptychites Walcotti HYATT and SMITH.
Owenites Koeneni HYATT and SMITH.
Xenaspis Marcoui HYATT and SMITH.
Ophiceras conf. *sakuntala* DIENER.
Inyoites Oweni HYATT and SMITH.
Pseudosageceras intermontanum HYATT and SMITH.
Lanceolites compactus HYATT and SMITH.
Aspenites acutus HYATT and SMITH.
Ussuria compressa HYATT and SMITH.
Prosphingites Austini HYATT and SMITH.

Flemingites is abundant in the *Hedenstroemia* beds of the Salt Range and the Himalayas, but unknown in northern Asia. In California it is represented by the group of *F. Rohilla*, and in Idaho by that group and more abundantly by the group of *F. Salya* DIENER (*F. cirrus* WHITE). *Ussuria* occurs in eastern Siberia, and is not known from southern Asia. The Californian form is specifically distinct from that in Idaho. *Pseudosageceras* is common in India, occurs in eastern Siberia, and is common both in California and Idaho. *Hedenstroemia* is rather common in the Salt Range, northern Asia, and also in Idaho. *Ophiceras* occurs in India, eastern Siberia, and both Idaho and California. *Otoceras* and *Medlicottia* appear to be lacking in the Lower Trias of America, probably because the equivalents of the *Otoceras* beds are as yet unknown there. It will be noted that some genera that are common in the *Meekoceras* beds of Idaho are laeking in the corresponding strata in California, for example *Hedenstroemia*, and *Cordillerites*; and that sometimes where the same genus occurs in both provinces it is represented by different species. This suggests a stight difference in age; and the abundance of the group of *Flemingites Salya* in Idaho, and its absence in California, suggests a slightly greater age for the *Meekoceras* beds of California. But there is nothing else, for the larger part of the fauna occurs in both provinces.

The *Meekoceras* fauna of southeastern Idaho is very closely allied to that of India, and belongs to the upper Brahmannic horizon. It is entirely unlike any fauna known in the Mediterranean region, or indeed anywhere outside of Asia.

The Tirolites beds. — In Paris Canyon, one mile west of Paris, Bear Lake County, Idaho, are found the *Tirolites* beds; these consist of gray calcareous shales, about 15 metres thick, and lie about 75 metres above the *Meekoceras* beds and 15 metres below the *Columbites* beds. All three horizons are exposed in a contiuous section in the same canyon, the

Meekoceras beds outcropping at the entrance to the canyon, the *Tirolites* beds on the sides, and the *Columbites* beds above them near the top.

The fauna of the *Tirolites* beds is decidedly the same as that of the upper Werfen or Campil beds of the Mediterranean region. Nothing comparable to it has been found in Asia, and it is probable that during the upper Werfen epoch there was some other connection between the American and Mediterranean regions than through India. This incursion of Mediterranean forms was only sporadic, for in the overlying *Columbites* beds, 15 metres higher up, the fauna is no longer Mediterranean in character.

In the *Tirolites* beds in Paris Canyon are found the following species:

Fauna of the Tirolites beds.

Dalmatites conf. *morlaccus* KITTL.
Tirolites conf. *cassianus* QUENSTEDT.
» » *Haueri* MOJSISOVICS.
» » *Smiriagini* MOJSISOVICS.
Dinarites sp. indet., Gruppe der *Nudi*.
Orthoceras sp. indet.
Nautilus sp. indet.
Pseudomonotis idahoensis MEEK.
» *Pealei* WHITE.
Rhynchonella sp. indet.
Pentacrinus sp. indet.

The Columbites beds. — The *Columbites* beds occur in Paris Canyon, southeastern Idaho, about 15 metres above the *Tirolites* horizon, and 90 metres above the *Meekoceras gracilitatis* beds. They consist of thin bedded brownish bituminous limestones, with the recognizable fossils in a single layer not more than ten centimetres thick. In this layer the fossils are abundant and exceedingly well preserved, being protected against solution and weathering by the bitumen, with which the rock is saturated.

The most abundant and characteristic element of this fauna is the genus *Columbites,* represented by five species, only one of which has been described. In addition to *Columbites* were found a doubtful species of *Tirolites,* two species of *Celtites,* one of Kingites, one each of *Prionolobus* and *Ophiceras*, three of *Meekoceras,* one of *Pseudosageceras*, fish spines, pelecypods and brachiopods. Of the species determined, the *Kingites* is very near to *Kingites Keyserlingi* Mojsisovics, *Prionolobus Jacksoni* is almost identical with »*Xenodiscus*« *Schmidti* Mojsisovics, and one species of *Columbites* is almost identical with a form described from the Olenek fauna by Mojsisovics under the name of »*Monophyllites*«.

This scanty fauna is at least closely allied with the Jakutic fauna of the Olenek River in Siberia, and gives us a proof of the age of the Olenek beds, for the Idaho formation still contains some characteristic species that lived in the *Meekoceras* epoch. It is, in the main, a boreal fauna, and its appearance marks a change in the faunal relations, and a cutting off of communication with the Mediterranean region through the Atlantic ocean.

Fauna of the Columbites beds.

Meekoceras pilatum Hyatt and Smith.
Prionolobus Jacksoni Hyatt and Smith.
Ophiceras Spencei Hyatt and Smith.
Kingites aff. *Keyserlingi* Mojsisovics.
Tirolites aff. *illyricus* Mojsisovics.
Pseudosageceras intermontanum Hyatt and Smith.
Celtites.
» an other species.
Columbites parisianus Hyatt and Smith.
» four other species.
Pseudharpoceras?
Nautilus sp. indet.
Orthoceras sp. indet.
Cosmacanthus elegans Evans.

The Middle Trias.

In the Middle Trias a certain kinship still persists between the marine faunas of western America and Asia, though this may be due as much to inheritance from similar ancestors, as to immigration. No species are any longer common to the two regions, and many genera, even, are different on opposite sides of the ocean. But at the same time a kinship between the American and the Mediterranean faunas begins to be noticeable, especially in the nodose ceratites and other members of the Ceratitidae. In the zone of *Ceratites trinodosus* in the West Humboldt Range of Nevada, out of more than one-hundred species, more than one-fourth are either identical with, or very closely related to, forms from this zone in the Mediterranean region. It is possible that during the Middle Trias a connection was established between these regions through some other way than the Indian branch of the old Central Mediterranean, or »Tethys«, probably through the Atlantic Ocean. It is not likely, however, that it was through the Boreal region, for the Boreal Middle Triassic fauna is unlike that of the Mediterranean. The faunas of the American and of the Mediterranean regions during the Middle Trias are more closely related to each other than either is to the Indian or to the Boreal fauna.

The Middle Trias of California. — The oldest fauna of the Middle Trias in America has been found in Inyo County, California, on the Union Wash trait from Owens Valley over the Inyo Range to Salinas Valley, about three miles southeast of the Reward mill. The fossiliferous beds consist of about two metres of black limestone, lying about 300 metres above the horizon with *Meekoceras gracilitatis*, which occurs in the same canyon. These beds may possibly belong to the Jakutic horizon, but the occurrence in them of *Parapopanoceras* and *Ptychites,* makes this improbable. Also *Hungarites* and *Acrochordiceras* are lacking in the *Meekoceras* beds and in the Jakutic *Columbites* beds of Idaho, and their appearance in America

marks a later epoch than the Jakutic, the character of their fauna is not that of the *Hedenstroemia* beds of India, hence they are regarded as correlative with the Hydaspic beds.

Fauna of the Parapopanoceras beds in California.

Tirolites pacificus HYATT and SMITH.
Keyserlingites? sp. indet.
Acrochordiceras sp. nov.
Hungarites Yatesi HYATT and SMITH.
Ptychites sp. nov.
Parapopanoceras Haugi HYATT and SMITH.
Xenodiscus Bittneri HYATT and SMITH.
» sp. nov.
Orthoceras sp. indet.
Undeterminable pelecypods.

Among these forms only *Tirolites pacificus* shows a great affinity to the Mediterranean fauna; the majority is Asiatic still. The *Hungarites* species are more similar to the Mediterranean forms than to the Asiatic, but this genus is widely distributed. The fauna has more affinity to that of the Arctic lower Muschelkalk, that is, to that of India, and, therefore, it seems possible, even probable, that at this time the American Trias province was connected on the one side with the Mediterranean region, on the other side with the Boreal province, but not with the Indian region.

The Middle Trias of Nevada. — The Geological Survey of California under J. D. WHITNEY discovered in the Humboldt Range of Nevada some fossiliferous limestones containing ammonites, referred by W. M. GABB[1] to the upper Trias, and correlated with the St. Cassian Formation of the Alps. Most of the species were obtained in the canyons on the eastern flanks of

[1] Palaeontology of California, Vol. I (1864).

the West Humboldt Range, although the data given by GABB are rather meager.

About ten years later the Geological Exploration of the Fortieth Parallel brought to light a considerable number of new species and genera from the Humboldt Range; these were descriped by F. B. MEEK[1], and referred to the St. Cassian formation of the upper Trias, although Professor ALPHEUS HYATT, who described the genera of cephalopods in the fauna, always adhered to the opinion that the formation belonged to the Muschelkalk. But it is likely that several different horizons are represented among the collections described by GABB and MEEK. »*Halorites Ramsaueri*« GABB and *Pseudomonitis subcircularis* GABB were found in the Humboldt region; both are characteristic of the uppermost Trias in California, and in Nevada I found them only in the *Pseudomonotis* slates, more then 300 metres above the Muschelkalk beds.

In several publications[2] Dr. E. VON MOJSISOVICS has referred the Humboldt fauna to the upper Trias, correlating them with the Fassanic substage of the Tyrolic series, and comparing them especially with the ceratite beds of Rikusen, Japan, and the Buchenstein beds of the Alps. Now, if the West Humboldt beds were the equivalents of the Buchenstein beds, they would still belong to the Muschelkalk. But, in fact, the fauna of the West Humboldt beds shows little affinity with the Rikusen beds of Japan, and not a great deal, with the Buchenstein beds of the Mediterranean. Instead of this the kinship is chiefly with the *Ceratites trinodosus* fauna of the Mediterranean region. The occurrence in these beds of *Ptychites, Hungarites, Beyrichites, Acrochordiceras, Ceratites*, and *Balatonites* would be enough to make certain the reference of the fauna to the Muschelkalk, as

[1] U. S. Geol. Expl. Fortieth Parallel, Vol. IV (1877).

[2] Arktische Triasfaunen (1886) pp. 147—150; and Beitr. zur Kenntnis der obertriadischen Cephalopoden Faunen des Himalaya (1896), pp. 692—697.

none of these genera in their typical forms occur higher up. In addition to this, many of the commonest species in the Middle Trias of the West Humboldt Range are most closely related to characteristic species in the Muschelkalk zone of *Ceratites trinodosus* of the Alps and Bosnia. The upper Anisic stage is certainly represented in Nevada, and the higher beds of the *Daonella dubia* shaly limestone may represent the lower Ladinic.

I have collected extensively in the Middle Trias of the West Humboldt Range for the past five years, and the collections have yielded the following forms:

Muschelkalk species from the West Humboldt Range.

Ceratites aff. *elegans* Mojsisovics.
» » *brembanus* Mojsisovics.
» » *luganensis* Merian.
» » *Loczyi* Arthaber.
» » *planus* Arthaber.
» *humboldtensis* Hyatt and Smith.
» *nevadanus* Mojsisovics.
» aff. *tuberosus* Arthaber.
» » *aniticus* Mojsisovics.
» *trinodosus* Mojsisovics.
» (*Gymnotoceras*) *Blakei* Gabb.
» » *Meeki* Mojsisovics.
» » aff. *Nathorsti* Mojsisovics.
» (*Hollandites*) » *Hidimba* Diener.
» » » *Voili* Oppel.
Cuecoceras bonae-vistae Hyatt and Smith.
Beyrichites rotelliformis Meek.
Anolcites aff. *Arminiae* Mojsisovics.
Anolcites Hyatti Smith.
» conf. *crassus* Hauer.
» *Meeki* Mojsisovics.
» *americanus* Mojsisovics.

Anolcites aff. *Elisabethae* Mojsisovics.
» *Whytneyi* Gabb.
Acrochordiceras Hyatti Meek.
Balatonites shoshonensis Hyatt and Smith.
Longobardites nevadanus Hyatt and Smith.
Eutomoceras Laubei Meek.
» *Dunni* Smith.
» conf. *Boeckhi* Hauer.
Halilucites aff. *plicatus* Hauer.
» » *intermedius* Hauer.
Sibyllites conf. *planorbis* Hauer.
» *Londerbocki* Hyatt and Smith.
Celtites aff. *epolensis* Mojsisovics.
» *Halli* Mojsisovics.
» conf. *Neumayri* Mojsisovics.
Monophyllites billingsianus Gabb.
Gymnites aff. *bosnensis* Hauer.
Lecanites Vogdesi Hyatt and Smith.
Ptychites Meeki Hyatt and Smith.
Sageceras Gabbi Mojsisovics.
Joannites Gabbi Meek.
» *nevadanus* Hyatt and Smith.
Germanonautilus Whitneyi Gabb.
Paranautilus multicameratus Gabb.
Orthoceras dubium Gabb.
Atractites conf. *crassirostris* Hauer.
» aff. *cylindricus* Hauer.
» conf. *tenuirostris* Hauer.
Daonella dubia Gabb.
» aff. *Taramellii* Mojsisovics.
Rhynchopterus obesus Gabb.
Sphaera Whitneyi Meek.
Modiomorpha? lata Meek.
» *ovata* Meek.
Myacites humboldtensis Gabb.

Corbula? Blakei Gabb.
Mytilus Homfrayi Gabb.
Avicula Homfrayi Gabb.
Myophoria alta Gabb.
Aulacothyris humboldtensis Gabb.
Rhynchonella lingulata Gabb.
» *aequiplicata* Gabb.
Spiriferina Homfrayi Gabb.
Cymbospondylus? grandi Leidy.
» *petrinus* Leidy.
» *piscosus* Leidy.

Beside these cited fossils also many other species were collected that still are undescribed and show nearer affinity to known forms. Those species, which are designated in the above as »conf.« were regarded as possibly identical with the species, with which they were compared, — at all events as very closely related to them. The species designated as »aff.« are not identical with the nominative ones, but are little further removed from them.

The group of *Ceratites elegans* (*Paraceratites* Hyatt), is largely of Mediterranean occurrence, but is also represented in the Indian Region. The group of *Hollandites* is almost exclusively Indian, but it is represented in Nevada by several fine species. The group of *Ceratites planus* is a Mediterranean type, and occurs abundantly in Nevada. *Gymnotoceras* is of Boreal affinities, but is far more abundant in Nevada than in the Boreal region. The species of *Beyrichites* and *Acrochordiceras* seem to be equally allied to Mediterranean and Indian types, but *Longobardites, Sageceras, Cuecoceras, Anolcites, Protrachyceras* and *Eutomoceras* are decidedly Mediterranean in character. There is a large number of species of *Anolcites* and *Protrachyceras* in the Middle Trias of Nevada, and these groups are fairly well represented in the Middle Trias of the Mediterranean region, while lacking in that horizon

in the rest of the world. The occurrence of *Balatonites* is also the same as that of *Anolcites*.

The fauna listed above, from the *Daonella dubia* beds of the West Humboldt Range of Nevada, shows a strong affinity with that of *Ceratites trinodosus* of the Mediterranean region, but also shows many elements that belong more properly to the lower Ladinic, equivalent of the Buchenstein fauna of the Alpine province. Such a mingling of faunas has been described from Bosnia by F. VON HAUER[1] and from Bakony in Hungary by F. FRECH,[2] and by G. VON ARTHABER.[3] The Han Bulog fauna and its equivalents show this mingling of Bosnian and Ladinic forms, which may be explained either by a mixing of the fossils in collecting from two horizons, or else by a survival of species from the *Ceratites trinodosus* horizon into later time. The latter explanation has been adopted by the European stratigraphers, and may very reasonably explain the same phenomenon in the American *Daonella* beds. The fauna of the restricted *Ceratites trinodosus* zone probably originated in the Mediterranean region and reached America by migration through the Atlantic waters. But the *Trachyceratea* which give the Ladinic aspect in America probably originated in the American region. Thus the West Humboldt fauna appears to be homotaxially equivalent to both the zone of *Ceratites trinodosus* and the lower part of the Ladinic, but the predominance of the Bosnian elements shows that the relationship is closer with the Bosnian than with the Buchenstein fauna.

The work of MOJSISOVICS, Über einige japanische Triasfossilien, gave an exaggerated idea of the relationship of the American to the Arctic-

[1] Beitr. z. Kennt. Cephal. aus der Trias von Bosnien, Theil I, 1892; Theil II, 1896; and Die Cephalopoden des Bosnischen Muschelkalkes von Han Bulog bei Sarajevo, 1887.

[2] Neue Cephalopoden aus den Buchensteiner, Wengener und Raibler Schichten des südlichen Bakony etc., 1903.

[3] Die Alpine Trias des Mediterran-Gebietes (1906), p. 444.

Pacific Triassic faunas. In that work Mojsisovics compared American and Japanese forms and named several American species, all based entirely on the figures published by Gabb and Meek. The reader not familiar with American species would infer that there was a close relationship to the Asiatic species described, which is very far from being the case. The Japanese material was too poor, and the American forms known up to that time were too few in number for any opinion to be based upon them and Mojsisovics saw only the poor figures given by Gabb and Meek. The rich faunas that I have collected in the Middle Trias of Nevada for many years past fair to show any relationship whatever to the Japanese, but to show such a distinctly Mediterranean character that a paleontologist from Austria might be set down in the Humboldt desert and he could hardly tell from the character of the fauna whether he was collecting in Bosnia or in Nevada.

The Upper Trias.

Plumas County, California. — The Geological Survey of California under Professor J. D. Whitney first discovered fossils characteristic of the Upper Trias in some shales in Genessee Valley on Indian Creek, Plumas County, California, near the northern end of the Sierra Nevada. Only the Upper Trias is represented in that section, the shales and limestones resting uncorformably on the Carboniferous. Only a few fossils were found here, but *Pseudomonotis subcircularis* Gabb, and *Halorites Ramsaueri* Gabb (= *H. americanus* Hyatt), were enough to determine the age of the beds. These, along with a few other species, were described by W. M. Gabb in Palaeontology of California, Vol. I (1864), in which also the first description of the Trias of Nevada was published.

Many years later Mr. J. S. Diller and Professor Alpheus Hyatt visited

that region and undertook a revision of the work of GABB. The section of the Trias of Plumas County is as follows:

3. *Pseudomonotis* slates, with *Pseudomonotis subcircularis*, *Halorites americanus*, and *Rhabdoceras Russelli* . . . . . 70 metres
2. Hosselkus limestone, with *Tropites* conf. *subbullatus*, *Juvavites*, *Arcestes*, and *Atractites* . . . . . 50 »
1. *Halobia* slates, with *Halobia superba*, *Tropites*, *Arcestes*, and *Atractites* . . . . . 35 »

This was the first recognition of a Karnic fauna outside of the Mediterranean region, and consequently has a greater historical importance than the meager fauna alone would warrant.

Mr. DILLER has described from the Taylorsville region, under the name of Foreman beds, a series of slates and conglomerates with plant remains, assigned by Prof. W. M. FONTAINE[1] to the Rhaetic. This shows that the Triassic marine history of California ended with the Pseudomonotis beds, and that during the Rhaetic epoch the land had encroached still further on the sea by the progressive westward uplift.

Shasta County, California. — In 1892 Dr. H. W. FAIRBANKS discovered some ammonite-bearing limestones about nine miles northeast of Copper City, Shasta County, near the trait over the divide between Squaw Creek and Pit River. These fossils were submitted to me for identification and proved to belong to the *Tropites subbullatus* fauna. I have since spent a part of most of the sommers since 1892 collecting in that region. The fossils are abundant and well preserved, and a large quantity of material has been accumulated. The general section of the Trias in Shasta County is as follows:

[1] Twentieth Annual Report, U. S. Geol. Survey, Part. II, 1900, p. 333.

General Section of the Trias in Shasta County.

			Metres
Noric		*Pseudomonotis* slates, with *P. subcircularis*	200
Karnic	Hosselkus limestone	*Spiriferina* beds, hard siliceous limestone	20
		Juvavites beds, siliceous limestone	30
		Tropites subbullatus beds, shaly limestone with *T. subbullatus, Trachyceras Lecontei, Sagenites Herbichi, Discotropites sandlingensis,* etc.	20
		Halobia slates, calcareous shales, with *Halobia superba* etc.	30
Ladinic		*Protrachyceras* conf. *Hom/rayi* slates, with *Halobia* conf. *rugosa*	30
Muschelkalk		Siliceous shales and conglomerates, with *Anolcites* conf. *Whitneyi, Ceratites* conf. *humboldtensis, Arcestes, Orthoceras* etc., of Silvertown's ferry on Pit River, about 500 metres below the fossiliferous limestone. Thickness probably	200

Most of the characteristic fossils were collected in the *Tropites subbullatus* beds, on Brock Mountain, between Squaw Creek and Pit River. The following list gives the principal species:

Karnic species from Brock Mountain, Shasta County, California.

Tropites subbullatus Hauer.
» *fusobullatus* Mojsisovics.
» *Dilleri* Smith.
» *torquillus* Mojsisovics.
» conf. *Morloti* Mojsisovics.
» » *Aurelii* Mojsisovics.
» » *Telleri* Mojsisovics.
Paratropites Dittmari Mojsisovics.
» *Sellai* Mojsisovics.
Discotropites sandlingensis Hauer.
» *Theron* Dittmar.
» conf. *Laurae* Mojsisovics.
Homerites semiglobosus Hauer.
Sagenites erinaceus Dittmar.
» *Herbichi* Mojsisovics.
Juvavites subintermittens Hyatt and Smith.
» *subinterruptus* Mojsisovics.
» conf. *Bacchus* Mojsisovics.
Gymnotropites americanus Hyatt and Smith.
Tornquistites obolinus Dittmar.
» *evolutus* Hyatt and Smith.
Polycyclus Henseli Oppel.
» *nodifer* Hyatt and Smith.
Tirolites foliaceus Dittmar.
Tropiceltites Frechi Hyatt and Smith.
Goniatites aff. *Gemmelaroi* Diener.
Discophyllites conf. *Ebneri* Mojsisovics.
Arpadites Gabbi Hyatt and Smith.
Californites Merriami Hyatt and Smith.

Clionites compressus Hyatt and Smith.
» *rugosus* Hyatt and Smith.
» *Fairbanksi* Hyatt and Smith.
» *robustus* Hyatt and Smith.
» *californicus* Hyatt and Smith.
Sandlingites Andersoni Hyatt and Smith.
Sirenites Lawsoni Hyatt and Smith.
Trachyceras Lecontei Hyatt and Smith.
» *shastense* Smith.
Hauerites Ashleyi Hyatt and Smith.
Dieneria Arthaberi Hyatt and Smith.
Paraganides californicus Hyatt and Smith.
Arcestes pacificus Hyatt and Smith.
Atractites Philippii Hyatt and Smith.
Cosmonautilus Dilleri Hyatt and Smith.
Proclydonautilus triadicus Mojsisovics.
Mojsvaroceras Turneri Hyatt and Smith.
Orthoceras shastense Hyatt and Smith.
Halobia superba Mojsisovics.
Myophoria sp. indet.
Terebratula sp. indet.
Rhynchonella sp. indet.
Pentacrinus sp. indet.
Shastasaurus pacificus Merriam.
» *Osmonti* Merriam.
» *Alexandrae* Merriam.
Toretocnemus californicus Merriam.
Delphinosaurus Perrini Merriam.
Merriamia Zitteli Merriam.
Thalattosaurus Alexandrae Merriam.

Among these forms cited above many are quite identical with Mediterranean species; some others are very related, but different. Also here, as in the Muschelkalk, the affinity of the American fauna to the Mediterranean is much greater than to the Indian, also it seems to be closer related to the

Mediterreanean fauna than the Indian. This justifies the assumption that in the Karnic epoch — although there could have been a connection with the Indian region — the chief direction of migration was from the Western America directly towards the Mediterranean province through the Atlantic region.

The Karnic horizon, zone of *Tropites subbullatus*, contains many elements common to the Mediterranean region and Western America, and many of them are also found in India, *Tropites subbullatus*, *T. torquillus*, *Paratropites Sellai*, *Discotropites sandlingensis*, *Sagenites Herbichi*, *S. erinaceus*, *Polycyclus Henseli*, and *Halobia superba* are common in both California and in the Tyrolian Alps, and many other species are very closely related. Many of these species are represented in India by forms that may be identical with them.

It is well known that the *Tropitidae* appeared as immigrants in the Mediterranean and Indian regions in the Upper Trias, without local ancestors. And is was formerly thought that this was also the case in the American region. But I have now found the probable ancestors of *Tropites* in the Middle Trias of Nevada, in which region the group appears to have originated, and to have spread to the rest of the world. The Karnic fauna is not yet known in Asia outside of India, and the only proof we have of the migration is the occurrence of similar species in the widely separated regions. The path of this migration can not be traced with certainty, but the recent discovery by Dr. CARLOS BURCKHARDT of a Karnic fauna in the State of Zacatecas in Mexico points to the Atlantic connection.

It should be noted that while *Trachyceras* is wholly extinct in the Mediterranean region before the epoch of *Tropites subbullatus* in America it is extremely abundant in the same beds and even in the same handspecimens with that species. This probably means that *Tropites* originated in the American waters as shown above, and reached the Mediterranean region later. In India a single specimen of *Trachyceras* has been found in the *Tropites* beds, and this can readily be explained as a survivor. No such explanation is

possible in the American beds, where the species of *Trachyceras*, represented by abundant material, number no less than six.

The Upper Trias, Noric horizon. Fossils of the Noric horizon, zone of *Pseudomonotis ochotica*, are known in Alaska, British Columbia, California, Nevada, and as far south as the coast of Peru. *Pseudomonotis ochotica* is widely distributed in Siberia and Japan, and is probably identical with the American *Pseudomonotis subcircularis*. This group is distinctly northern Asiatic in origin, and never reached the western Mediterranean waters. But very recently, according to G. VON ARTHABER (Alpine Trias, 1905, p. 440), *P. ochotica* has been discovered in the Crimea, having migrated thither from the northeast. The appearance of this group in western America marks another Asiatic immigration, but this time it came from the north. We see here a reversion to the conditions of the Lower Trias. The widespread occurence of beds with *Pseudomonotis ochotica* around the northern shores of the Pacific and around the Arctic Ocean shows a transgression ot the sea on what was formerly a continental border. These forms were endemic in the Boreal region, and made their way southward when the transgression of the sea opened the way, on both sides of the Pacific. Of course, this may not have had anything to do with climate, but at the close of the Karnic epoch the fauna of western America shows a sudden change of facies from the Indian-Mediterranean character to that of Siberia, which shows, at least a change in connections. A passage from the Arctic to the Pacific was reopened between Asia and America, and the Boreal, though not necessarily cold-water, type came through, making its way southward.

Deep water, cutting off Asia from America, would have separated the two Triassic regions just as effectively as cold water, but since there was free passage for the group of *Pseudomonotis ochotica* down both sides of the Pacific, it is strange that it did not reach Tropical India, and that the Tropical Indian forms ceased temporarily to come to America. If such changes

had occured in Tertiary time we would say without hesitation that the Boreal invasion marked an influx of cold water from the Arctic Ocean through the open passage between Asia and America.

Pseudomonotis ochotica has also been found on New Caledonia and in other places in that region. It may be, however, that in the Indian Ocean the Boreal and the Mediterranean facies were temporarily united, in which case the presence of *Pseudomonotis ochotica* would not necessarily be a proof of the southward extension of a lower temperature. A modern instance of the some restricted dispersion of a northern form is seen in the distribution of the representatives of the Atlantic *Purpura lapillus* in the North Pacific. This group is abundant in the North Atlantic, and has made its way through the Boreal region into the Pacific, being modified into several geographic races. On the western coast of North America, where there are no sudden changes in the temperature of the sea water, this group has made its way as far south as Margarita Bay, in lat. 24° N., mean temperature 23° C. On the Asiatic side it has made its way through Bering Sea down the shores of Kamschatka with the cold water, but bas been stopped by the sudden change of temperature at Hakodadi, lat. 41° N., Japan, mean temperature 11° C., where the warm Japan current meets the cold current from Bering Sea. That this is not an accident of distribution is shown by the fact that the group of *Purpura lapillus* has, in the Atlantic, a similar distribution, and for the same reasons. On the African side it reaches lat. 32° N., mean temperature 19° C., and on the American side it is barred back by the sudden change of temperature at lat. 42° N., mean temperature 11° C.[1] There can be no doubt that the temperature, or rather evenness of change of temperature, controls the distribution of *Purpura lapillus* now, and it would seem only reasonable to suppose that similar conditions in the Trias caused the unequal distribution of *Pseudomonotis ochotica.*

[1] A. H. Cooke, Cambridge Natural History, III, p. 363, 1895.

The *Pseudomonotis* beds are well developed in the West Humboldt Range, Nevada, where they show about 270 metres of black slates, with *Pseudomonotis subcircularis* GABB, *Arcestes Andersoni* HYATT and SMITH, *Rhabdoceras Russelli* HYATT, *Halorites americanus* HYATT, *Choristoceras* sp. indet., and *Placites humboldtensis* HYATT and SMITH. These same beds with a similar fauna are also known in the Star Canyon on the east side of Star Peak.

In California the *Pseudomonotis* beds occur on Indian Creek in Genessee Valley, Plumas County, and on Brock Mt., Shasta County, but with the fossils much less numerous and well preserved than in Nevada.

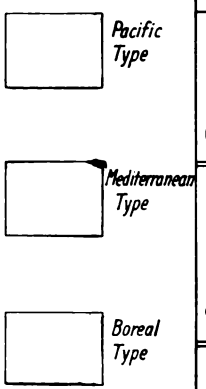
Summary of later Stratigraphy of Western America.

Lias. It is probable that during the Lias the southward migration of the Boreal type of animals was interrupted, for the *Arietites* group, which was characteristic of that epoch in Europe, is known in California and Nevada, as well as in Mexico and South America. It was, however, practically universal, having been found also in the Indian region, though not as yet from the Jurassic Arctic sea. In the Upper Lias the genus *Amaltheus* was widely distributed in Europe and in the Boreal region, but has not yet been found in North America. It is known from New Grenada, associated with a typical Mediterranean fauna. It seems probable that the Lias of California and Nevada is merely a northward extension of the South American type.

Middle Jura. In California the Middle Jura, like the Lias, appears to have been of Mediterranean type, but in the Black Hills we have a southward extension of a fauna characteristic of northern Europe, and of the region around the northern Pacific Ocean. This boreal type is extensively developed in Alaska and in northern Siberia, and its appearance in the Black Hills marks the beginning of another incursion from the north.

Upper Jura. The incursion of the Boreal fauna into America which

Geographical relations of the American Trias.



		Mediterranean region	Oriental region	Boreal region	West-American region
Recent			Marine mollusc-fauna of Japan		Marine mollusc-fauna of California
Quaternary					
					Warm water marine fauna of California
			Cold water marine fauna of Japan		Cold water marine fauna of California
Tertiary	Neogene	Cold water marine fauna	Cold water marine fauna of Japan		Cold water marine fauna of California
	Eogene	Venericardia planicosta Zone			Venericardia planicosta Zone ←
Cretaceous	Upper				
		Schloenbachia Fauna of Europe ←	Schloenbachia Fauna of Japan, South-India and East-Africa →	..... →	Schloenbachia Fauna of California
	Lower			Aucella Fauna of North-Europe, North-Asia and Alaska	Aucella Fauna of the Knaxville Strata in California
Jura	Upper			Cardioceras Fauna with Aucella in Russia	Cardioceras Fauna with Aucella in California
	Middle		Mediterranean Type in India	Cadoceras Fauna of Alaska and the Boreal region	Mediterranean Type in California
	Lower	Arietites Fauna	Arietites Fauna in the Indian Ocean		Arietites Fauna in California and Nevada ←
Trias	Upper		Pseudomonotis ochotica Fauna in Japan ←	Pseudomonotis ochotica Fauna in Alaska and North-Siberia →	Pseudomonotis ochotica Fauna in California and Nevada
		Tropites subbullatus Fauna →	Tropites subbullatus Fauna in India	Dawsonites Fauna of the Arctic Ocean	Tropites subbullatus Fauna in California
	Middle				
		Ceratites trinodosus Fauna	Ceratites trinodosus Fauna	Ceratites Fauna of Spitzbergen	Ceratites trinodosus Fauna in Nevada
				Posidonomya Fauna of Spitzbergen	Parapopanoceras Fauna in California
	Lower	Tirolites cassianus Fauna	Hedenstroemia Fauna of India	Olenikites Fauna of North-Siberia →	Columbites Fauna in Idaho
					Tirolites Fauna in Idaho
			Meekoceras Fauna of India →	..... →	Meekoceras Fauna in California and Idaho
Carboniferous		Atlantic Type	Asiatic Type in India, Japan and China	Asiatic Type in Alaska and Siberia	Asiatic Type in California

began in the Middle Jura reached further southward and westward in the Mariposa epoch of the Upper Jura, down through California to San Luis Potosi in Mexico. This fauna is characterized by the genera *Cardioceras* and *Aucella*, which had their home in northern Europe only sporadically as the result of incursions. POMPECKJ[1] has shown in several papers that a Polar sea existed in the Middle and Upper Jura and Lower Cretaceous, from which incursions were made from time to time into the more southerly regions, when changes in physical geography made it possible. He has also shown that the *Aucella* fauna had its real home in that region, where it formed a truly genetic series, and that it appeared only sporadically in other regions, where the species speedily degenerated and the fauna becomes extinct unless replenished by another migration.

The suggestion of climatic influence on the dispersion of marine animals in the Upper Jurassic is very strong, for the *Aucella* did not make its way into the Indian Ocean, although the way was probably open. It went only where the conditions of its own proper habitat existed, if only temporarily. Even so conservative a naturalist as J. D. DANA[2] admits that in Jurassic time there was a cold current to the southeast along the western coast of North America, making possible the migration of *Aucella* from the Boreal into warm temperature or even subtropical waters.

Aucella did, however, make its way into northern India probably from southern Russia, during a time of extension of the sea in that direction in the Kimmeridge and Tithonian epochs.[3]

---

[1] Über Aucellen etc. N. J. für Min., Geol. und Pal. XIV, 343, 1901 and Jura Fossilien aus Alaska, Verh. k. o. Russ. Gesell. (St. Petersburg), XXXVIII, 376, 1901. The Jurassic Fauna of Cape Flora, Franz Josef Land; The Norwegian North Polar Expedition 1893—1896, Scientific Results, p. 141, 1898.

[2] Manual of Geology (1895), p. 794.

[3] S. NIKITIN, Bemerkungen über die Jura-Ablagerungen des Himalayas und Mittelasiens. Neues Jahrb. für Min., Geol. und Pal., II, 124, 1889.

Lower Cretaceous. After the Jurassic beds were laid down there was in California a break in sedimentation, and the uplift of the Sierra Nevada took place. But it was orogenic, and although widespread, it did not affect the geographic relations, for with the opening of the Cretaceous the same northern types were still there. *Aucella* was still the most characteristic genus, and along with it were many species of ammonites closely related to Russian species. *Aucella crassicollis* is even identical with a characteristic Russian form. These Knoxville species were probably in part immigrants from the Boreal region, although some of them may have been modified descendants from species that were endemic in the American waters. Before the end of the Knoxville epoch, while the Boreal forms still persisted, *Lytoceras* and *Phylloceras*, genera that were never found in northern Europe and Asia, appeared in the Cretaceous beds of the western coast of America. These forms seem to have been endemic in the warm regions of southern Europe and Asia, and their appearance marks a resumption of interchange between India and America, around the shore-line formed by closing the gap between Asia and Alaska. In proof that the gap was really closed, it may be said that the flora of the upper Knoxville beds appears to indicate a warm temperate climate,[1] which would mean that the cold current from the Arctic Ocean had been cut off by a rise of the land.

During the later Cretaceous *Aucella* made its way into the Tropics, around the Pacific Ocean, so that its later occurrence gives no evidence of southward extension of Boreal climatic conditions.[2]

Upper Cretaceous. With the opening of the Horsetown epoch all reminiscences of the Boreal fauna are gone, and the Tropical character of

---

[1] W. M. Fontaine, Notes on some Fossil Plants from the Shasta Group of California and Oregon. Mon. XLVIII, U. S. Geol. Survey (1905), pp. 221—273.

[2] Pompeckj, Über Aucellen und Aucellen-ähnliche Formen, Neues Jahrb. für Min. etc., XIV, 348, 1901.

the inhabitants of the sea on the western coast of America is marked. A close affinity and even identity of species with the Indian fauna characterizes this epoch. And it is noteworthy that the Puget Sound Horsetown and Chico faunas are even more closely allied to those of India than are those of California. Migration appears to have been free between Asia and America, but the species did not all range so far south as California, thus indicating the direction from which they came. Of course, not all the marine forms on the west coast of North America came from Asia, but the Asiatic portion is the only one that we can trace to its source.

The following species that occur in the Horsetown and Lower Chico of western America are regarded by KOSSMAT[1] as identical with species in southern India:

Lytoceras Kayei FORBES.
» *tymotheanum* MAYOR.
» *cala* FORBES.
» *indra* FORBES.
Hamites glaber WHITEAVES.
Schloenbachia inflata SOWERBY.
Acanthoceras Turneri WHITE.
Pachydiscus otacodensis STOLICZKA.
» *arialurensis* STOLICZKA.
Desmoceras diphylloides FORBES.
» *latidorsatum* MICHELIN.
Puzosia planulata SOWERBY.
Hauericeras Gardeni BAILEY.
Phylloceras Whiteavesi KOSSMAT.
» *Velledae* MICHELIN (cited as the probable equivalent of *P. ramosum* MEEK).

[1] Beitr. Pal. und Geol. Österreich-Ungarns und des Orients, IX, Parts 3 and 4, 1895.

Besides the above, F. M. ANDERSON[1] describes the following species from the lower Chico beds as identical with Indian forms: *Schloenbachia propinqua* STOLICZKA, *S. blanfordiana* STOLICZKA, *Desmoceras sugata* FORBES. Nearly all these species that are common to the western coast of America and India also occur in Japan, and many of them also in eastern Africa. They are, then, tropical or subtropical in habitat. Whether the appearance of the *Aucella* fauna of the Upper Jura and the Lower Cretaceous in the North Pacific means cold water or not, the appearance of the Indian forms in the same region can only be interpreted to mean that a warm temperature prevailed there at that time, and that conditions were equable around the old shore line from India as far as California.

With the closing of the passage between Asia and America, the warm Japan current, which is now chilled by the cold southwesterly current from Bering Sea, would warm up the whole coast line and make the waters of western America warmer than they are now. We also have evidence that the temperature of the land in the northern hemisphere was warmer than at present, for HEER[2] has shown that the Cretaceous floras of Greenland, Spitzbergen and Alaska contained cycads and other forms indicating a mean temperature of about 21° C.

Upper Chico. In the upper Chico horizon (Senonian), of California and Oregon the connection with India appears to cease, and a path of migration from the interior Cretaceous sea of America seems to have been opened.[3] Several species of pelecypods are identical with species from the upper Missouri province, and some of the ammonites are closely allied.

Eocene. During the early Tertiary, or Tejon epoch, in California we

[1] Cretaceous Deposits of the Pacific Coast, Proc. Calif. Acad. Sci., III, Ser. Geol., vol. II, No. 1, 1902.

[2] Flora Fossilis Arctica, VI and VII, 1882—83.

[3] F. M. ANDERSON, Cretaceous Deposits of the Pacific Coast, 1902, p. 59.

have no evidence of any migration from Asia, but it is plain that a connection existed with the Eocene sea of the Atlantic region. *Venericardia planicosta*, which is abundant in the Claiborne beds of the states around the Gulf of Mexico, has been found at a number of places in Oregon and California, and it appears to be more common in southern California than anywhere else on the western coast. Other species of this fauna may be identical with Atlantic forms, at any rate some are closely related, and it is probable that the passage lay to the south of California.

Miocene. In the middle Tertiary the passage to the Atlantic seems to have been closed, and there is no evidence that communication was resumed with Asia. The Miocene fauna of California seems to have been largely endemic, for no Atlantic species are found in it and the only possible admixture consists of forms from the south, and of circumboreal species that made their way down from the north. But towards the end of Miocene time the land appears to have risen in the north, cutting off the Arctic Ocean from the Pacific, and allowing land plants to migrate from Asia to North America. ASA GRAY[1] has shown that in the Miocene northeastern Asia and northwestern America were connected, that over those regions there existed a flora like that of warm temperate latitudes at the present time, and that this connection persisted almost to the beginning of the Glacial epoch.

We have no evidence that a migration of marine invertebrates from Asia began as early as the upper Miocene but they would naturally be slower in their movements than land plants, and consequently would lag behind them. The Tertiary uplift of land in the northern hemisphere may be correlated with the widespread orogenic uplift of the Coast Ranges on the Pacific side of North America, which in California and Oregon is known to have come near the end of the Miocene, and before the Pliocene beds were laid down.

[1] Amer. Jour. Sci. (3), CXVI, 1895, 1878.

Pliocene. There is good geologic evidence that the landbridge between Asia and America still existed in the Pliocene, for there seems to have been a constant interchange of vertebrates in that quarter,[1] in the Miocene, Pliocene, and early Pleistocene. Also students of other groups find it necessary to postulate such a connection to explain the migration of animals. A. E. ORTMANN[2] says that the identity of some of the fresh-water crustaceans in Siberia and Alaska proves a recent connection of those parts, and that this union of the continents began in the middle of the Cretaceous and lasted into the lower Pleistocene. This is in harmony with the fact that the climate of western America was subtropical or warm temperate from the middle of the Cretaceous until about the end of the Miocene. G. M. DAWSON[3] is of the opinion that in the Pliocene the Pacific coast of North America stood about 900 feet higher than now, which would be ample to connect the two continents, and cut off the cold water from the North Pacific. And we still have evidence of this former elevation of the Alaskan region, for in the Aleutian Islands, commonly regarded as a chain of new volcanoes, granite appears in several places.[4]

At this time the marine faunas of Japan and the western coast of America begin to be remarkably similar with many species identical, which can only mean that intermigration had set up along shore line. And the identical species are not merely circumboreal, for many of them have never been found in the Boreal region.

The rise of the land in the northern hemishere, as shown by the distribution of land and fresh-water animals, would cut off the southward cold current from the Arctic Sea, and prevent the chilling of the Japan

[1] H. F. OSBORN, Science, XI, 571, 1900.

[2] Proc. Amer. Phil. Soc. XLI, 291, 299 and 316, 1902.

[3] Quoted in DANA's Manual of Geology, 949, 1895.

[4] J. E. SPURR, U. S. Geol. Survey, 20th Ann. Rept., Part VII, 234, 1900.

current south of Bering Sea. The Japan current would then warm the shores of Alaska, and produce a mild temperature along the old shore line from Japan to California. That it did so is shown by the similarity of the Pliocene faunas of the two now separated regions. At first there was naturally a mixture of Boreal and Japanese forms, for D. Brauns[1] has shown that the Pliocene of Japan is related to the »Crag« of England; and the upper Pliocene of California appears to indicate a temperature of the sea-water somewhat lower than at present. At any rate, it is clear that the climate around the North Pacific in Pliocene time was merely temperate; this is shown by the fact that while we have an immigration of Japanese species, no Indian forms came with them, as they did in the Upper Cretaceous, when the climate appears to have been subtropical.

Pleistocene and Recent Faunal Relations.

San Pedro epoch. With the beginning of the Pleistocene the same conditions existed as in the upper Pliocene. Japanese species still abound in the marine fauna, and the character is still somewhat boreal,[2] which may be due to a survival of forms that came in during the colder Pliocene epoch. The land connection with Asia still existed, and free exchange of land animals between Asia and America still went on.

As the waters of the Californian coast gradually became warmer, Mexican species began to creep northward, and in the upper San Pedro fauna we find a number of species that now live only in the Tropics, and

---

[1] Geology of the Environs of Tokio, Mem. Science Dept., Univ. of Tokio, No. 4, pp. 1—82, 1881.

[2] Delos and Ralph Arnold, The Marine Pliocene and Pleistocene Stratigraphy of the coast of Southern California, Jour. Geol., vol. X, No. 2, pp. 117—138 (1902).

have become extinct on the Californian coast.[1] This does not mean that connection with Japan was cut off, but that the continuation of the conditions that allowed Japanese species to migrate to California finally allowed marine animals to make their way up the coast also.

Glacialists postulate an elevation of the land in the northern hemisphere, in the period preceding and during the Glacial epoch; this undoubtedly cut off the migration of land animals and plants between Asia and America. When this affected intercommunication along the shore-line we do not know, but after the close of the San Pedro epoch the Asiatic immigration ceased, and also subtropical elements of the marine fauna of California became extinct. With the subsidence following the Glacial epoch conditions returned to the normal, and intermigration with Japan was not resumed. It was too cold for the perpetuation of the warm-water species from the south, though not too cold for the Japanese species to live on in the Californian waters. But the Asiatic colonists in America were not replenished by immigration from the mother country, and those that are found in the Californian province are merely survivors.

Relations of the living faunas of the west coast to that of Japan. The table below shows the living species that are common to the western coast of North America and the Japanese province. The number of species is very large, especially when we consider the fact that they are in different zoologic regions, and separated by more than five thousand miles. Migration of shore forms can not possibly be going on now, for while the distance is no bar to them, the deep water at the end of the Aleutian chain of islands would effectually check all passage in either direction. And the sudden changes in temperature through which marine animals would have to pass are an equally effectual barrier. We have seen already how even a circum-

[1] RALPH ARNOLD, Mem. Calif. Acad. Science, III, 29 et seq., 1903.

boreal group as that of *Purpura lapillus*, is checked in its southward passage where the cold current from Bering Sea meets the warm Japan current. Such changes are even more impassable to warm water species.

In the present similarity of the marine fauna of Japan and the western coast of America we have an example of provinces that were recently connected, but which are now separated by deep water and by differences of temperature in between, while the conditions still remain similar in the two provinces. This separation, however, has existed long enough for some of the species to have become differentiated by evolution, for some to have become extinct in one province while still living in the other, and for the total faunas to have become much changed by immigration from other regions.

At first sight it would seem that the intermigration of the marine faunas has been more recent than the exchange of the land animals and plants between Asia and America. And indeed this may be so, for a subsidence that would cut off effectually all land organisms might not interfere with the migration of marine animals living at moderate depths. For instance, *Haliotis*, a distinctly Asiatic type is not known on the west coast of America before the upper San Pedro epoch, and has now made its way southward below California. On the other hand, we must remember the conservative character of marine faunas. Where in the land Pleistocene faunas most of the species have been replaced by others, of the marine Pleistocene animals only a very small percentage has become extinct. We must also note that, of the species now common to the two sides, a large proportion is known to have existed in Tertiary time, and probably nearly all in Pleistocene. In the time that has elapsed since the two provinces were separated, *Lucina acutilineata*, which abounded during the Pliocene in both Japan and California and is still living in Puget Sound, has become extinct in Japan. *Mya arenaria*, also abundant in the Pliocene in both provinces, has become extinct

Tertiary and living species.

	Japanese Province			West American Province		
	Pliocene	Pleistocene	Living	Pliocene	Pleistocene	Living
Barbatia gradata Sowerby . . .			×			×
Cardium blandum Gould			×	×	×	×
» *corbis* Martyn	×		×		×	×
Chlamydochiton annulatus Pallas .			×			×
Crepidula grandis Midd.			×	×		
Cryptochiton Stelleri Midd.			×			×
Diplodonta orbella Gould	×		×		×	×
Dentalium hexagonnm Sowerby . .	×		×	×	×	×
Haliotis Kamtschatkana Jonas . . .	×		×			×
Laqueus californicus Koch			×	×	×	×
Lasœa rubra Montagu	×		×		×	×
Leptothyra Carpenteri Pillsbry . .			×			×
Lima orientalis Adams	×		×			×
Littorina sitkana Philippi			×			×
Lucina borealis Linné	×			×	×	×
Macoma edulis Nuttall			×		×	×
» *inquinata* Gould			×		×	×
» *nasuta* Conrad	×		×	×	×	×
» *secta* Conrad			×	×	×	×
Modiola flabellata Gould	×			×		
Macron Kelletii A. Adams			×		×	×
Mopalia muscosa Gould			×			×
Murex foliatus Gmelin			×		×	×
Mya arenaria Linné	×		×	×		×

Tertiary and living species.

	Japanese Province			West American Province		
	Pliocene	Pleistocene	Living	Pliocene	Pleistocene	Living
Mytilus edulis Linné	×		×		×	×
Nucula Cobboldiae Sowerby	×		×	?		
Natica clausa Broderip			×		×	
Panopœa generosa Gould	×		×	×	×	×
Pecten caurinus Gould	?		?	×	×	×
» *jessoensis* Stimson	×		×			
» *hericeus* Gould			×	×	×	×
» *islandicus* Müller			×	×	×	×
Placuanomia macroschisma Deshayes			×	×	×	×
Purpura crispata Chemnitz			×	×	×	×
» *lapillus* Linné	×		×	×		×
Sanguinolaria Nuttalli Conrad			×			×
Saxidomus Nuttalli Conrad			?	×	×	×
Siphonalia Kelleti Hinds			×		×	×
Siliqua patula Dixon			×			×
Solen sicarius Gould			×	×	×	×
Tapes staminea Conrad			×	×	×	×
Tellina bodegensis Hinds			×	×	×	×
Terebratulina caput-serpentis Linné	×		×			×
Tresus Nuttalli Conrad	×		×	×	×	×
Tritonium oregonense Redfield			×		×	×
Trophon orpheus Gould			×	×	×	×
Velutina laevigata Pennant			×		×	×
Venus Kennerlyi Carpenter			×			×

in California. while it still persists in Japan. It has, however been introduced artificially late in the nineteenth century and now abounds in most of the bays on the west coast. On the Alaskan coast *Mya arenaria* did not become extinct, though it did not make its way down to California. It is also probable that *Pecten caurinus* on the west coast and *P. jessoensis* in Japan have become differentiated from their common ancestors.

All this points to rather ancient separation, not later than the upper San Pedro epoch, at which time the warm-water fauna came up from the south, and never reached Japan.

Summary.

Present physiography. The living faunas of the Japanese province and of the western coast of North America are rather closely allied, with a large number of species in common, and they live under approximately the same conditions, although they are in widely separated regions. Between them lies a stretch of shore-line running up to lat. 60° N., around the southern shores of Alaska and the Aleutian Islands, but interrupted by the deep channel east of Kamchatka. Also there is a great difference of temperature between them. The warm Japan current, with an average maximum temperature of 30° C., flows past Japan, swings to the northeast, south of the Aleutian chain towards America, and parts off Puget Sound, one branch flowing northwestward along the Alaskan coast, and the main branch southeastward down towards California. But in lat. 42° N., off Hakodadi, Japan, it is met by the cold current from Bering Sea along the coast of Kamchatka, and from there on the current is merely temperate, being reduced to about 19° C. It tempers the Alaskan waters, but makes the waters along the shores of California colder than they should be, as compared with similar latitudes elsewhere. These currents have been fully described by Professor

GEORGE DAVIDSON[1] who has made many hydrographic investigations in that region; and by Dr. W. H. DALL,[2] who verified much of the work of Professor DAVIDSON, but showed that there was no northward branch of the Japan current extending up into Bering Sea.

At present the migration of shallow water species is stopped by the depth of the channel at the end of the Aleutian chain, and also by the cold water that extends southwestward from Bering Sea. But a rise of 200 meters would close Bering Strait, and about one-half of Bering Sea, giving a shoreline coinciding approximately with a great circle. It would then leave the Aleutian chain as a long narrow peninsula reaching out from Alaska towards Siberia, separated from Kamchatka by a rather narrow but deep channel; while the mainland of Alaska and Siberia would be united by a broad land-bridge. This change in the height of the land would cut off all influx of cold water from the Arctic Sea, and the Japan current, not being chilled by cold water from Bering Sea, would still be warm along the Aleutian Islands and the Alaskan coast, and no doubt the tempering effect would be felt even as far south as California. A rise of 2,000 meters would not connect Aleutian chain with Kamchatka, but at least would give a stretch of shoal water along which migration would be easy for shore forms. In any case there would be a shore line with temperate or warm water all the way from Japan to California.

While it is not likely that the land in the northern part of the Pacific has, in recent geologic times, stood 2,000 meters higher than now, it has certainly stood several hundred feet higher, and whether much or little, we know from the migrations of land plants and animals between Asia and America that there has been a land-bridge. Now in any case, whether in

[1] Report Supt. U. S. Geodetic Survey, 1867, Appendix No. 18, p. 202, 1869.

[2] Rept. Supt. U. S. Coast and Geod. Survey for 1880, Appendix No. 16, p. 322.

the present or in the past, similar contemporaneous faunas mean similar conditions, and identical species mean immigration from one region to the other, or from a third region to both. In the case of Japan and the west coast of America the only outside region that can have furnished elements to both is the Boreal region, and circumboreal species in both provinces are well known. But a large majority of the species now common to both provinces are not circumboreal. Thus intermigration is the only satisfactory explanation of the present distribution of most of the species that are common to Japan and California.

Unlike species living contemporaneously in similar conditions can only mean separation by physical barriers; these to the marine shore-animals are: a land-mass, deep-water, or great difference of temperature in between. The two latter are the only barriers that can ever have been interposed between Japan and the west coast of America, and a rise of 200 meters would remove both.

The hypothesis of former migration around the Alaskan-Aleutian shoreline explains satisfactorily the close relationship between the living marine animals of Japan and California, while the present interruption and the length of time during which it has persisted explain the unlikeness of the greater part of the two faunas. A periodic recurrence of this interruption acounts for the periodically recurring unlikeness of faunas of these two provinces in the past, and also for the fact that the successive faunas of California do not form a genetic series, but rather one showing periodically diverse origin and characters. With this in mind we can find out where the successive migrations came from, and why the present fauna shows such a commingling of forms derived partly from Asia and partly from the more southerly regions of America.

Past physiography. The old idea of uniformity of climate all over the earth before the Tertiary period still remains as an undercurrent in the minds

of geologists, and stands in the way of any theory that accepts the influence of differences of temperature in causing faunal differences in the past. STANTON[1] denies that the change of character of the Cretaceous fauna of the west coast at the end of the Knoxville epoch, from the Boreal to the Indian type, can be attributed to change in climate. Others have criticized NEUMAYR's[2] theory of climatic zones in Jurassic and Cretaceous times, and there can be no doubt that NEUMAYR carried his theories entirely too far, reconstructing ancient physical geography on very little evidence. But the fact that NEUMAYR was mistaken in many things is no argument that the principle was wrong. No doubt geographic connections and presence or absence of opportunities for free intercommunication were of just as great importance as differences of temperature in governing the distribution of faunas in the past, as well as now. But it will not do to leave climate entirely out of the reckoning.

The assumption of a uniform temperature over the earth before the Tertiary period rests on an insecure basis. If any former climate was uniform, it must have been warm, and the temperature must have been warmer the further we go back in geologic history. And yet we have evidence that the temperature was not uniform even in the Paleozoic. It is well known that over parts of India, Australia and South Africa there is good evidence that there was a Permian glacial epoch, while we know from abundant contemporary floras in other parts of the earth that this glaciation was not universal. In this, then, we have proof that there was great diversity of climate even in the Paleozoic era.

Now it would be absurd to account for the difference between the cold-

[1] Jour. Geol., V, 598, 1897.

[2] Klimatische Zonen während der Jura- und Kreidezeit. Denkschr. k. Akad. Wiss. Wien, XLVII, 1883.

water faunas of California in the Pliocene and lower San Pedro formations and the warm-water fauna of the upper San Pedro, and the contrast between the latter and the present cooler water fauna of the California coast, on any other hypothesis than differences of temperature. For all this is based on species that are still living, where we know the exact conditions of geographic connection and temperature under which they live, and by which their distribution is governed. These differences of temparature are slight, and the changes in physical geography that caused them are insignificant, thoug far-reaching in their effects. All this, of course, applies only to the shore lines affected by the marine currents, and does not necessarily have anything to do with continental climates.

It would seem equally rational to explain similar distribution in the past by the same hypothesis. The faunal relations between western America and eastern Asia from the Trias to the present were the same, Asiatic facies alternating with periodically recurring invasions of the Boreal type, and on occasional invasion by a Mediterranean fauna through Atlantic waters. If differences of temperature can account for the connections and separations of the living faunas, they must be taken into account in explaining similar connections and separations in Tertiary, Cretaceous, and even Jurassic and Triassic times.

On homotaxis. The similarity of the fossil faunas of the Orient to those of the west coast of America is, indeed, surprising, but not more so than that of the living faunas of Japan and the Californian province. It is important in the correlation of these deposits to determine whether they are really synchronous. Ever since Huxley[1] cast doubt upon the simultaneous occurrence of the same faunas in widely separated regions, geologists have

[1] Quart. Jour. Geol. Soc., London, XVIII, 40 - 54, 1862.

been inclined to assume that this similarity is good proof that they were not really synchronous. But we know that the present faunas of Japan and the Californian province are synchronous and similar, with many identical species, although they are in different geographie regions. And there is no more reason to assume that the similar Mesozoic faunas of the two regions were not synchronous than there is for the present time. The modern instance shows that they may just as well have been synchronous as not.

Biologists are often sceptical as to identity of species in separated regions in the past, on the ground that the criteria for determining fossils are not so exact as those applied to recent forms. But this is also fallacious, since the recent shells of Japan and California have been subjected to most careful examination by critical conchologists, and many species found to be identical. There is, therefore, no presumption against the identity of similar species in the two regions of Cretaceous, Jurassic, or even Triassic age.

On the permanence of the shore-line. The marine sediments and their fossils around the North Pacific, from the Trias on to the present time, show that the shore-line has been, during all that time, approximately as it is now. There is no reason to theorize about great change in physical geography, when such a simple matter as the periodic opening and closing of Bering Strait by rising and sinking of the land in that quarter will account satisfactorily for all the changes in character and distribution of the marine faunas. E. HAUG,[1] in his studies of the distribution of Mesozoic formations and organisms, has invented the theory that during Mesozoic time a great continent existed where the Pacific Ocean now is. Whatever may be true of the rest of that ocean, there is no necessity for supposing a continent to have existed formerly in the North Pacific, when all the facts may be

[1] Les Geosynclinaux et les Aires continentales. Bul. Soc. Géol., France (3) XXVIII, 646.

explained more easily on the hypothesis of the permanence of the shore-line approximately as it is now. This has nothing to do with the general proposition of the permanence of continental plateaus and oceanic basins, but merely proves a particular case, and suggests that some of the ancient oceans, that are to be found on maps purporting to represent the former continents and seas, may be only epicontinental seas.

DATE DUE			

STANFORD UNIVERSITY LIBRARIES
STANFORD, CALIFORNIA 94305